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DRAINAGE PROGRAM

KESTERSON RESERVOIR
1990 SITE MANAGEMENT PLAN

March 1990

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INTRODUCTION AND PURPOSE

The purpose of this document is to present the Site Management Plan for Kesterson Reservoir for 1990. This document describes actions taken to date, current conditions at the Kesterson Reservoir, and plans for further actions.

ACTIONS COMPLETED

The Department of Interior (Department) has completed two major actions with respect to cleanup of Kesterson Reservoir. These are: termination of subsurface agricultural drainage water flow into Kesterson Reservoir; and filling of potential ephemeral pool areas in the Reservoir with soil. In addition, the Bureau of Reclamation (Reclamation) has been actively managed Kesterson Reservoir since the completion of filling to minimize potential impacts to wildlife and ground or surface waters from selenium contamination.

Termination of Subsurface Agricultural Drainage Water Flow

The source of contamination at Kesterson Reservoir was irrigated agricultural tile drainage water carried to the Reservoir via the San Luis Drain (SLD). On April 3, 1985, the Department entered into an agreement with Westlands Water District to curtail drainwater discharges to the SLD. Drainwater discharge to the SLD was discontinued entirely by June 30, 1986. Since August 1986 when drainwater remaining in the SLD quit flowing into the Reservoir, no drainwater has been discharged to Kesterson Reservoir. Hence, since that time, there has been no further input of drainwater contaminants to Kesterson Reservoir. Due to the natural geochemistry of the ground-water aquifer beneath Kesterson Reservoir, termination of drainwater discharge to Kesterson Reservoir essentially eliminated the threat of further selenium contamination of the ground-water aquifer.

Filling of Kesterson Reservoir Ephemeral Pools

Monitoring conducted at Kesterson Reservoir demonstrated that residual contamination had manifested itself in significant wildlife impacts primarily through the aquatic food chain. In order to eliminate this exposure pathway, Reclamation dewatered the Reservoir ponds and filled low-lying areas (ephemeral pools) of the Reservoir with 1,050,437 cubic yards of material in 1988. These actions have essentially eliminated aquatic habitat at the Reservoir and, thus, broken the food chain through which aquatic wildlife impacts were manifested in the past.

1989 Management Actions

Management actions completed during 1989 focused on areas where rainwater puddled during the winter of 1988-1989, and on minimizing endangered species use of the site. Approximately 5 acres in Ponds 2, 3, and 9 were deep ripped in order to increase soil permeability and to prevent any further puddle formation. About 800 cubic yards of earth fill material was added to a 1-acre area of Pond 3 where persistent puddles formed during the winter of 1988-1989.

A 4-acre area in Pond 9 was disced to discourage nesting use by snowy plovers. Also, research into effective long-term dissipation and management techniques for the remaining selenium inventory and monitoring of impacts continued.

CURRENT CONDITIONS AT KESTERSON RESERVOIR

Ground Water

Reclamation currently samples 27 shallow water quality monitoring wells and 41 pollutant plume monitoring wells at and adjacent to Kesterson Reservoir. This monitoring is done on a quarterly basis, as specified in the Central Valley Regional Water Quality Control Board's Monitoring and Reporting Program No. 87-149. The monitoring program was developed in collaboration with the Regional Board to detect and monitor migration of selenium and other constituents under and downgradient of Kesterson Reservoir. Results from this monitoring program have confirmed that the extent of selenium migration into the aquifer has been minimal and that the several small plumes of seleniferous drainwater detected between 1984 and 1986 have now all but disappeared.

At present, only four wells exceed the designated "plume detection level" of 10 ppb selenium, compared to about 30 wells in the period from 1984-1986. Selenium concentrations in these four wells range from 11 to 40 ppb. The rapid decline in selenium concentrations detected after delivery of agricultural drainage water ceased in 1986 is consistent with research findings that naturally occurring geochemical/microbial processes transform and immobilize soluble selenium in the shallow aquifer underlying the Kesterson Reservoir area.

The agricultural tile drainage water discharged into Kesterson Reservoir also contained elevated levels of salts and boron. Unlike selenium, these constituents moved freely into the aquifer and remain mobile in this environment. The residual plume extends from several feet to about 140-feet below the ground surface with an estimated average depth of about 60-feet. Ground-water samples from water quality monitoring wells adjacent to the northeast border of the Reservoir indicate that this plume is confined to a band that extends no more than 1,000 feet from

the Reservoir in this direction. Water quality samples to the east of the Reservoir, adjacent to Kesterson Ponds 1, 2, and 5, are limited; however, geophysical measurements of soil conductivity have indicated that the plume of high total dissolved solids (TDS) does not extend more than 1,200 feet from the edge of the Reservoir in the easterly direction.

Surface Water

Ephemeral pools formed by rising ground water have not occurred at Kesterson Reservoir since the completion of filling. Although rainfall was below normal levels in 1988, 1989, and through February 1990, heavy rainfall events did occur during the winter of 1988 and 1989. After rainfall events greater than about 0.5 inch, many shallow puddles formed on top of filled habitat. These puddles formed where there were slight depressions and where soils were heavily compacted by equipment during the filling operation. There has been no significant puddling in either the grassland or open habitats. Immediately after heavy rainfall events puddles were estimated to cover about 1 percent of the filled habitat. In a matter of days many puddles disappeared and persistent puddles (those lasting more than 1 week) in 1988-1989 covered about 0.25 percent of the entire Reservoir. In the winter of 1988-1989 a few puddles persisted for weeks and usually overlapped later rainfall events. The largest of these puddles, found in Trisection 1, varied between 0.25 and 0.35 acres in size. No persistent puddles have formed in these areas since they were deep ripped and filled.

Reservoir-wide, the geometric mean selenium concentrations in rain puddles was 4.0 ppb ($n = 53$; range = $<1 - 50$). A general trend of decreasing selenium concentration from south to north was observed. This trend is similar to trends observed in the water extractable fraction of soil selenium. The highest concentrations were found in puddles in Pond 3. In late February, aquatic invertebrates were discovered in a group of puddles in Pond 3. The selenium concentration in these puddles ranged from 44 to 50 ppb. No vegetation was observed in these puddles, but widgeongrass seeds and signs of wildlife activity were observed around their edges. Seeds and aquatic beetles were collected for selenium analysis. Widgeongrass seeds had a geometric mean selenium concentration of 622 ppm ($n = 3$; range = 570 - 680). The aquatic beetles had a geometric mean selenium concentration of 15.3 ppm ($n = 5$; range = 13 - 19) which is comparable to levels found in terrestrial beetles collected during the 1989 sampling year. The area where these puddles formed were ripped and earth filled during the summer of 1989. These actions appear to have been successful as no significant puddles have formed in this area during the winter of 1989-1990.

During the current 1989-1990 winter season, we have observed that some puddling continues to occur. We are monitoring puddles that

form on a regular basis. Analysis of samples from these puddles has not yet been completed.

Biota

Three major habitat types presently exist at Kesterson Reservoir: filled areas covering about 710 acres; grassland areas covering about 400 acres; and open (disced former cattail) areas covering about 170 acres. A summary of selenium concentrations found in plants and invertebrates collected in 1988 and 1989 is in Tables 1 and 2.

The filled area is covered primarily by annual plant species dominated by burning bush, clover, annual grasses, prickly lettuce and in some areas mustard. Mustard was only found in restricted areas in Trisection 2. The geometric mean selenium levels in plants collected from filled habitat is 2.9 ppm (n = 103; range = 0.1 - 82).

The grassland areas are dominated by saltgrass and have been extensively sampled in the past. The geometric mean selenium concentration in all plants collected in 1988 and 1989 is 3.5 ppm (n = 96; range = 0.6 - 32). Sampling of plants and invertebrates has indicated that selenium levels are relatively low compared to selenium levels found in the aquatic habitats which formerly existed at the site. The geometric mean selenium concentration in all grassland plants sampled since August 1988, is 3.66 ppm (n = 455; range = 0.1 - 82). The geometric mean selenium concentration in all grassland invertebrates, excluding sowbugs, sampled since August 1988 is 7.7 ppm (n = 363; range = 0.1 - 78). Much higher selenium levels (geometric mean = 57 ppm, n = 54; range = 23 - 210) have been measured in sow bugs. These levels are apparently related to similarly high selenium levels in soil litter where sow bugs live and forage. High selenium levels in the soil litter are attributed to disposition of sediments and vegetation in the past when grassland areas were occasionally flooded with drainwater. The importance of the litter-sow bug food chain is unknown, but no sow bugs were found in the contents of the 54 bird and 148 small mammal stomachs examined to date.

Open areas consist principally of disced cattail residue. These areas were not filled because they were above the target fill elevation, and were disced to eliminate tricolored blackbird habitat. As a result of discing, the organic sediment layer, which has elevated selenium levels, and cattail residue were mixed with underlying soil. A low growing groundcover, consisting of clover, prickly lettuce, burning bush, annual grasses, and other invader plant species, is colonizing this habitat type. Analysis of these plants show a geometric mean selenium concentration of 4.6 ppm (n = 112; range = 0.4 - 38). Invertebrate samples from this habitat type show an overall

Table 1
KESTERSON RESERVOIR
1989 PLANT SELENIUM CONCENTRATIONS
 (ppm dry weight)

DESCRIPTION	N	GEOMETRIC MEAN	RANGE
GRASSLAND			
alkali heath	36	3.8	1.1 - 32
alkali weed	18	3.5	0.9 - 8.5
prickly lettuce	18	6.1	1.2 - 20
salt grass	36	2.7	0.6 - 8.6
salt grass seed	18	1.2	0.2 - 4.7
FILLED			
alkali heath	15	4.1	0.4 - 28
alkali weed	24	5.6	1.0 - 29
annual grass	27	1.3	0.2 - 9.4
annual grass seed	18	1.1	0.2 - 7.0
burning bush	25	2.8	0.1 - 16
clover	17	1.4	0.2 - 13
clover seed	18	2.2	0.3 - 18
mustard	18	14	2.9 - 82
mustard seed	18	4.8	1.5 - 13
prickly lettuce	18	4.3	1.3 - 18
OPEN			
alkali heath	17	2.6	0.4 - 10
alkali weed	15	2.4	0.9 - 9.1
annual grass	17	6.8	1.2 - 38
annual grass seed	17	6.1	2.8 - 13
burning bush	36	2.1	0.3 - 16
clover	27	8.4	1.4 - 27
clover seed	18	8.2	2.9 - 25
prickly lettuce	36	3.9	0.6 - 16

Table 2
KESTERSON RESERVOIR
1989 INVERTEBRATE SELENIUM CONCENTRATIONS
(ppm dry weight)

DESCRIPTION	N	GEOMETRIC MEAN	RANGE
GRASSLAND			
grasshoppers	22	4.2	2.0 - 16
beetles	27	13	1.9 - 78
crickets	22	6.9	1.0 - 21
sowbugs	25	58	23 - 87
mixed aerials	30	6.4	2.0 - 18
spiders	19	11	2.0 - 40
FILLED			
grasshoppers	15	3.1	0.7 - 9.6
beetles	13	8.1	0.1 - 26
crickets	4	4.8	3.5 - 6.7
sowbugs	1	32	
mixed aerials	21	3.8	2.0 - 8.3
spiders	11	9.9	2.0 - 30
OPEN			
grasshoppers	18	6.4	2.0 - 25
beetles	19	17	8.3 - 41
crickets	15	13	6.3 - 23
sowbugs	7	61	32 - 120
mixed aerials	22	5.8	2.8 - 18
spiders	15	14	3.0 - 84

geometric mean selenium concentration of 10 ppm (n = 81; range = 2 - 61).

Bird use of the Reservoir has changed substantially. Drying and filling of the Reservoir has made the site unattractive to nesting tricolored blackbirds and the aquatic bird species in which impacts have been observed in the past. However, the Reservoir is presently being used by terrestrial bird species such as meadowlarks, horned larks, killdeer, and sparrows. Adult western meadowlarks were collected in 1988 and 1989. The geometric mean selenium level in livers of meadowlarks collected in 1989 was 16 ppm (n = 10; range = 4.8 - 36) and in livers from meadowlarks collected in 1988 the geometric mean was 23 ppm (n = 15; range 8.4 - 76). These levels are elevated when compared to liver selenium levels in meadowlarks collected from Volta in 1988 (4.1 ppm, n = 5; range = 3.3 - 4.7). Selenium concentrations in livers of other birds which are similar to these concentrations found in Kesterson Reservoir meadowlarks are known to have produced reproductive impairment. However, there are interspecific differences in how selenium affects birds. No abnormalities were found in any of the meadowlarks collected. All the meadowlarks appeared healthy, as determined by the condition of the integuments, internal organs and the amount of fat and muscle. Elevated selenium levels were found in meadowlark eggs collected in 1988 and 1989 (1988 geometric mean = 23 ppm; n = 2; range = 22 - 24 and 1989 geometric mean = 10 ppm; n = 5; range = 4.8 - 17). The geometric mean selenium concentrations in eggs collected in 1988 from other terrestrial bird species ranged from 1.7 ppm (n = 1) in mourning doves to 19 ppm (n = 15; range = 7.6 - 58) in killdeer. In 1989 geometric mean selenium concentrations ranged from 2.5 ppm (n = 2; range = 1.3 - 4.7) in mourning doves to 6.6 ppm (n = 6; range 4.2 - 15) in killdeer. No selenium related embryotoxicity was found in terrestrial bird species observed during the 1988 and 1989 nesting seasons. The last bird death apparently related to selenium toxicosis at the Reservoir was a dead coot salvaged on July 3, 1988.

Results of analysis of small mammals collected at Kesterson beginning in February 1989 indicate that whole body selenium concentrations are not significantly different than those sampled in 1988, except deer mice which were significantly lower in 1989 than in 1988. No adverse reproductive or growth impact to small mammals resulting from selenium has been observed at Kesterson Reservoir. Likewise, a study of raccoons in 1986 at the Reservoir found no adverse impacts from selenium. A 1986-1988 study of the endangered San Joaquin kit fox found limited use of the Reservoir by this species and no negative effect of selenium levels at Kesterson Reservoir on kit fox. However, the upland habitat now present at Kesterson Reservoir has resulted in an environment that may be more attractive to the kit fox. Two of eleven coyotes collected within Kesterson Reservoir as part of

the kit fox study had liver selenium levels within the range associated with selenium toxicosis in domestic dogs, and one of these two showed clinical signs associated with selenium toxicosis. The study also documented that small mammals accounted for 98 percent of the remains in kit fox scats collected from the Kesterson Reservoir area and 69 percent of the stomach contents of coyotes collected from the Reservoir. American coots were the second most important food item (28 percent) in the Kesterson Reservoir area coyote diet. Because of 1) the selenium accumulation observed in coyotes collected from Kesterson Reservoir, 2) continued elevated concentrations in small mammals, and 3) potentially better kit fox habitat produced by filling wetlands, kit fox use of the Reservoir continues to be monitored.

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Selenium levels in some biota at Kesterson Reservoir continue to be elevated above background levels and above levels that have been observed to result in impacts in the presence of drainwater. This observation is tempered by the fact that no impacts related to selenium toxicosis have been observed in birds or mammals since the elimination of standing water and the completion of filling. Management activities at Kesterson Reservoir are therefore focused on activities that minimize exposure of wildlife to elevated levels of selenium and eliminate aquatic habitat, while continuing to monitor for impacts and to conduct research into long term selenium dissipation techniques.

Grassland Areas

Selenium levels in the saltgrass areas of the Reservoir are generally low and these are the most stable habitats. The vegetative cover assists in minimizing surface water and no puddling has been observed in these areas. Monitoring of biota and selenium levels will continue. No direct management actions are proposed for these areas at this time.

Filled Areas

Filled areas are becoming covered with a variety of plants that generally have low levels of selenium. Further plant cover will assist in minimizing the occurrence of puddles. Disturbance of the soil would disrupt this plant cover and also might tend to bring buried selenium to the surface. No direct management actions for the filled areas are therefore proposed, other than treatment of puddles as they occur.

Open Areas

Approximately one-half of the open area habitat will be disced. The entire open area was disced at the time of the filling

operation in order to eliminate standing cattails. Since that time the open habitat has become re-vegetated with clover, prickly lettuce, burning bush, annual grasses, and other invading plant species. The open areas tend to have higher selenium levels than other Reservoir habitats and, although no adverse impacts on wildlife have yet been observed, discing will be done on about one-half of the open area in order to evaluate its effectiveness in minimizing or eliminating potential contamination pathways. All of the open habitat is not being discd in order to observe succession in the plant community and to determine if open habitat will remain safe without ongoing management.

Surface Water

Rainwater puddle monitoring data from 1989-1990 will be evaluated and any areas where persistent rainwater puddles may form in the winter of 1989-1990 will be discd, deep-ripped and/or filled.

There remains continuing uncertainty as to conditions at the Reservoir in the event of an unusually wet year. In a wet year there is the potential that extensive surface water could occur at the Reservoir as well as on surrounding lands. However, since the Reservoir is still enclosed by dikes, there is no surface outlet for water at the Reservoir. It is therefore conceivable that while surrounding lands drain, surface water at the Reservoir could slowly evaporate and infiltrate, concentrating constituents and providing attractive habitat for shorebirds and other species during the spring months when such conditions would be particularly undesirable. In such an event, current management options would include intensive hazing and/or sterilization of the areas. Another option may be to avoid such conditions by restoring natural drainage conditions at the site. This will of course require careful consideration of the advantages and disadvantages of such an action. We intend to explore, in consultation with Regional Board staff, a contingency surface drainage plan that could be implemented in anticipation of or in the event of unusually wet conditions.

Monitoring

An intensive monitoring program is ongoing at Kesterson Reservoir and will be continued. Monitoring of water quality and biota is designed to detect any adverse effects from contamination at Kesterson Reservoir as well as any migration of contaminants offsite. Reclamation will continue to provide the results of its monitoring routinely to the California Regional Water Quality Control Board - Central Valley Region, as specified in Monitoring and Reporting Program No. 87-149. Since dewatering of the Reservoir and filling of ephemeral pools, the emphasis of the biological monitoring has shifted to detection of any adverse effects to wildlife associated with the dry habitats now present

at Kesterson Reservoir. Continued emphasis will be placed on this effort to verify the lack of impacts associated with the dry land habitats. In addition, we are routinely monitoring any surface puddles that form at the Reservoir and in the event of heavy rainfall resulting in significant surface water at the Reservoir, more intensive monitoring will be implemented in order to rapidly identify any potential aquatic exposure pathways.

Research

Research activities aimed at identifying mechanisms for removal of selenium from soils will continue. Research activities are focused on two different management strategies including (1) management actions that optimize removal of selenium from surface soils (top 6 inches) through microbial volatilization and (2) management actions that remove selenium from the entire profile by a combination of plant uptake, plant volatilization, and microbial volatilization. The two major field scale experiments addressing these management options will continue. In addition, due to the continuing promise demonstrated by the microbial volatilization experiments in Pond 4 and with San Luis Drain sediments, a pilot project of microbial volatilization will begin in an open area of Pond 2. The pilot project will be carried out in a 2-acre test plot. A combination of irrigation and tillage will be used to stimulate microbial volatilization of selenium. Irrigation rates and tillage frequency will be geared towards what would be practical for large scale implementation at the Reservoir.

In addition to research activities aimed at identifying dissipative processes, ongoing research aimed at evaluating a no-action management alternative will continue. These investigations, in conjunction with the intensive biological and ground-water monitoring programs, provide information on the behavior of selenium in this environment and the risks or lack thereof to ground water, surface water, and biota.



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